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ORIGINAL RESEARCH

RELIABILITY AND MINIMAL DETECTABLE CHANGE OF THE UPPER QUARTER Y-BALANCE TEST IN HEALTHY ADOLESCENTS AGED 12 TO 17 YEARS

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ABSTRACT

Purpose/Background: There are a few studies investigating the reproducibility of the Upper Quarter Y Balance Test (YBT-UQ) in adults. However, no study has determined test-retest reliability and the minimal detectable change of the YBT-UQ in adolescents from different age cohorts. The aim of the present study was to establish test-retest reliability and minimal detectable change of the YBT-UQ in a sample of healthy adolescents.

Methods: In a school setting, 111 students (59 female, 52 male) aged 12-17 years performed the YBT-UQ twice, separated by one week. Normalized maximal reach distances (% arm length) for all three directions (i.e., medial, inferolateral, superolateral) and the composite score were used as outcome measures. Intra-class correlation coefficient (ICC3,1) and standard error of measurement (SEM) were calculated to assess both relative and absolute test-retest reliability. In addition, the minimal detectable change (MDC95%), an index that is defined as the minimal amount of change in performance that falls outside the measurement error or performance changes due to variability was determined.

Results: Irrespective of age cohort, reach arm, and reach direction, the measure of relative reliability ranged from "moderate-to-good" to "excellent" ICC values and the proxy of absolute reliability was rather small (i.e., SEM ≤ 7.6%). The MDC95% needed to identify relevant effects in repeated measurements of the YBT-UQ performance ranged between 4.8% and 21.1%, depending on age, reach arm, and reach direction.

Conclusions: The detected values imply that the YBT-UQ is a reliable field test that can be used to detect changes of upper quarter mobility/stability in healthy adolescents aged 12-17 years.

Level of Evidence: 2b

Key Words: adolescent, motor control, movement system, practical relevance, reproducibility, school setting, upper quarter mobility/stability

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INTRODUCTION

The Upper Quarter Y Balance Test (YBT-UQ) is a field-based method used to investigate upper quarter mobility and stability.[1-3] From a practical perspective it is important to know whether the results obtained from the YBT-UQ are reliable. In other words, to be certain that differences between test and retest assessment of YBT-UQ performance can be considered "real" and outside the error range, reliable measures on an individuals' performance are needed.[4] Further, distinct ranges of meaningful change need to be established. This allows practitioners to derive an accurate evaluation on the magnitude of changes between repeated YBT-UQ performance assessments.

Previous studies[1,2] on the test-retest reliability of the YBT-UQ have investigated healthy young adults, only. For example, Gorman et al.[1] examined test-retest reliability (between-test period: 20 minutes) of the YBT-UQ in 22 subjects (10 men, 12 women) aged 19-47 years and found "excellent" intraclass correlation coefficients (ICC) ranging between 0.80-0.99; irrespective of reach direction. Further, Westrick et al.[2] determined test-retest reliability (between-test period: 28 days) in 13 subjects. The obtained ICC values ranged from 0.91-0.92, which is indicative of "excellent" reproducibility. However, transferring these results obtained from adults to adolescents appears to be questionable, given that anthropometric and physiological differences due to growth and maturation exist.[5] As a consequence, performance levels achieved during the assessment of upper quarter mobility and stability may differ between age groups. For example, Borms and Cools[3] showed age-related differences in upper-extremity functional performance (i.e., YBT-UQ, Closed Kinetic Chain Upper Extremity Stability test, Seated Medicine Ball Throw test) in 206 adults (age range: 18-50 years). For the YBT-UQ, the 18- to 25-year-olds showed significantly better performance data compared to the 26- to 33-year-olds and the 34- to 50-year-olds, indicating an age-related reduction of upper-extremity function.

There is no study available that has determined test-retest reliability and minimal detectable change of the YBT-UQ in healthy adolescents including males and females from several age cohorts. Given the anthropometric and physiological differences between adolescents and adults, the aim of the present study was to establish test-retest reliability and minimal detectable change of the YBT-UQ in a sample of healthy adolescents aged 12-17 years.

METHODS

Participants

One-hundred twenty students in grades 6-11 (i.e., 12-17 years) were recruited from randomly chosen urban public schools. The characteristics of the students are shown in Table 1. Students were excluded from study participation if they (1) were outside of the aforementioned age range, (2) had a musculoskeletal, neurological or orthopedic disorder during the last three months prior to the beginning of the study, (3) had other medical conditions that could have affected their ability to execute the YBT-UQ or (4) performed the test or retest only. Nine students were excluded from study participation because they performed only the test / retest (n = 3) or were below (n = 3) / above (n = 3) the age range. As a consequence, 111 (93%) of the initially recruited subjects were included in the present study. Prior to the start of the study, participants' assent and parents' written informed consent was obtained. The study protocol was approved by the Human Ethics Committee at the University of Duisburg-Essen, Faculty of Educational Sciences.

Procedures

All participants performed the YBT-UQ twice, separated by one week during physical education (PE) classes in the school setting. Upon entering the gym, all participants received standardized verbal instructions and a visual demonstration regarding the testing procedure that included the assessment of arm dominance[6] and anthropometric variables followed by performance measurement in the YBT-UQ.

Assessment of anthropometric variables

Standing height was assessed with shoes off to the nearest 1.0 cm with a stadiometer (seca 217, Basel, Switzerland). Further, body mass was determined in light clothing and without shoes to the nearest 100 g with an electronic scale (seca 803, Basel, Switzerland). Body mass index was calculated using body mass divided by height squared (kg/m^2). For

Table 1. *Characteristics of the study participants (N = 111) by age cohort.*

Characteristic	12 yrs (n=14)	13 yrs (n=20)	14 yrs (n=24)	15 yrs (n=20)	16 yrs (n=18)	17 yrs (n=15)
Sex (f/m)	6/8	7/13	13/11	11/9	13/5	9/6
Height (cm)	160.5 ± 9.9	167.2 ± 8.8	168.4 ± 8.7	169.7 ± 8.7	168.5 ± 8.8	167.7 ± 10.4
Mass (kg)	48.4 ± 10.8	52.1 ± 10.1	59.3 ± 10.2	62.7 ± 15.8	62.1 ± 11.8	64.8 ± 12.3
BMI (kg/m^2)	18.7 ± 2.6	18.7 ± 3.6	21.0 ± 3.5	21.7 ± 4.5	21.7 ± 2.9	23.0 ± 3.3
Left arm length (cm)	81.6 ± 6.3	81.9 ± 4.7	84.4 ± 4.2	85.8 ± 5.5	85.5 ± 5.1	86.2 ± 5.1
Right arm length (cm)	81.6 ± 6.9	81.9 ± 4.9	84.6 ± 4.2	86.0 ± 5.3	85.6 ± 4.9	86.3 ± 5.0
Arm dominance (l/r)	(2/12)	(0/20)	(2/22)	(1/19)	(1/17)	(0/15)

Values are mean values ± standard deviations. BMI = body mass index; f = female; m = male; l = left; r = right.

normalization purposes, right and left arm length (cm) was determined with a cloth tape measure in accordance to the YBT-UQ test instructions provided by Plisky.[7]

Assessment of Upper Quarter Y Balance Test performance

YBT-UQ performance was assessed using the commercially available Y-Balance- Test-Kit (Functional Movement Systems, Chatham, USA) that was positioned on the gym floor. The Y-Balance-Test-Kit consists of a centralized platform to which three polyvinyl chloride pipes are attached representing the medial (MD), inferolateral (IL), and superolateral (SL) reach directions. Each pipe is marked in 0.5-cm increments for measurement purposes and equipped with a moveable reach indicator. Each participant was instructed to reach with one arm as far as possible while maintaining his/her push-up position in the MD, IL, and SL directions (Figure 1 A-C). The YBT-UQ was performed with the left and right arm. Prior to its execution, standardized instructions and demonstrations were provided. Three practice trials were conducted followed by three data-collection trials. Participants started with the right thumb placed behind the starting line that is marked on the centralized platform in a weight bearing one-arm push-up position with feet shoulder width apart. Afterwards, the participant sequentially moved the reach indicator with the left hand in the three directions as indicated by YBT-UQ

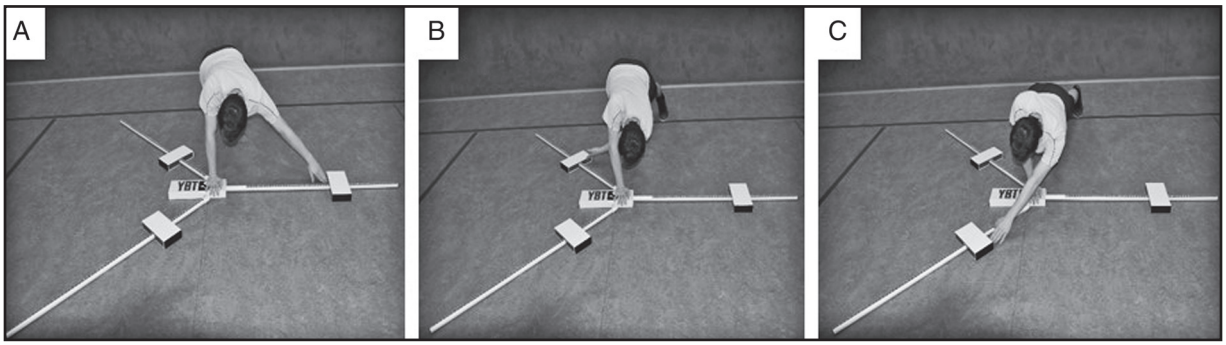

Figure 1. *Participant performing the Upper Quarter Y-Balance Test medial (A), inferolateral (B), and superolateral (C) reach.*

test instructions. This procedure was repeated until three valid trials in each reach direction were registered. Subsequently, participants completed three trials in the same manner with the opposite arm. In order to prevent effects of fatigue, participants rested for one minute between trials. After each reach, the obtained distance (i.e., from the center of the centralized platform to the maximal reach indicator distance) was documented to the closest 0.5 cm. Trials were discarded and repeated if the participants (1) did not maintain the one-arm push-up position at any point during the trial (i.e., touched down to the floor with the reach hand), (2) did not maintain reach hand contact with the reach indicator (i.e., shoved the reach indicator), (3) used the reach indicator for support (i.e., placed reach hand on top of the reach indicator) or (4) failed to return the reach hand to the starting position under control. Due to the amount of time needed for administering the YBT-UQ (i.e., three practice trials followed by three data-collection trials), two skilled examiners documented the reach distances in a group setting (i.e., examiner-to-student ratio of 1 to 5). The same examiners completed the test and retest for a particular group of subjects after they had trained their competence for YBT-UQ assessment in a study course. The normalized maximal reach distance per reach direction and arm was used as an outcome measure and calculated as follows: normalized maximal reach distance (% arm length [AL]) = (absolute maximal reach distance [cm]) / AL [cm]) × 100. Further, the normalized composite score ([CS] i.e., sum of the three maximal reach distances per reach direction) per arm was calculated by using the following formula and additionally used as outcome measure: CS (% AL) = ((MD + IL + SL) / (AL × 3)) × 100.

Statistical analyses

Descriptive statistics (i.e., group mean values ± standard deviations [SDs]) were calculated for the maximum distance reached in each of the three directions for both arms. An independent samples t-test was used to quantify YBT-UQ performance differences between females and males and a dependent samples t-test was performed to detect performance differences between the dominant and the non-dominant arm. Relative reliability was assessed using the ICC3,1 and the 95% confidence interval (CI).[8] In accordance to Fleiss[9], ICC ≥ 0.75 was considered "excellent", 0.40 < ICC < 0.75 was considered "moderate-to-good", and ICC < 0.40 was considered "poor". The absolute reliability of the data was determined using the standard error of measurement (SEM).[10] The lower the SEM value, the more reliable the measurement. In addition, Bland–Altman plots[11] were used to define the magnitude of agreement between test-retest values. Here, the performance difference between the test and retest measurements were plotted against the mean of the respective measurements.[11] Bland and Altman[11] recommended that 95% of the data points should lie within the mean ± 1.96 SD (i.e., limit of agreement) of the differences for the test and retest measurements. Further, we determined the minimal detectable change (MDC95%). The MDC95% is an index used to define the difference needed between repeated measures on one subject for the difference in the measures to be considered real.[4,8] All statistical analyses were performed using SPSS software (version 24.0, SPSS Inc., Chicago, IL, USA). The significance level was set at $p < 0.05$.

RESULTS

YBT-UQ performance

Group mean values and SDs for the normalized (% AL) YBT-UQ performance by age are presented in Table 2. For the left arm reach, performance data ranged between 85.4-99.9%, 72.8-92.7%, and 58.8-66.3% for the MD, IL, and SL direction, respectively. The corresponding CS ranged from 74.4-83.8%. With respect to the right arm reach, YBT-UQ performance ranged between 84.3-98.3% (MD direction), 72.3-91.0% (IL direction), and 56.7-63.0% (SL direction). The respective CS ranged from 72.7-82.8%. Except for the right arm reach in the IL direction ($p = 0.035$; lower in girls than in boys), no significant differences between female and male participants were detected. Further, the limb comparison revealed no statistically significant differences between the dominant and the non-dominant arm for any of the three reach directions or the CS.

Reliability

Irrespective of age cohort, reach arm, and reach direction, the ICC3,1 values ranged from "moderate-to-good" to "excellent", i.e. from 0.67-0.90 for

Table 2. *Upper Quarter Y Balance Test performance data for the test and retest assessment by age cohort.*

	12 yrs (n=14)		13 yrs (n=20)		14 yrs (n=24)		15 yrs (n=20)		16 yrs (n=18)		17 yrs (n=15)	
	Test	Retest	Test	Retest	Test	Retest	Test	Retest	Test	Retest	Test	Retest
Left arm reach												
MD (% AL)	85.4 ± 9.6	86.8 ± 11.1	93.5 ± 8.1	93.2 ± 11.4	92.9 ± 6.2	92.6 ± 9.4	97.1 ± 11.1	99.9 ± 10.3	95.6 ± 13.0	95.5 ± 16.0	93.9 ± 12.7	97.2 ± 11.2
IL (% AL)	79.0 ± 9.5	77.5 ± 8.8	87.2 ± 13.7	92.7 ± 21.1	83.2 ± 13.9	78.2 ± 11.9	78.9 ± 9.6	78.9 ± 12.7	72.9 ± 10.9	72.8 ± 10.9	74.5 ± 10.7	73.5 ± 11.4
SL (% AL)	58.8 ± 7.6	60.3 ± 12.2	65.7 ± 10.9	65.6 ± 11.3	66.3 ± 12.7	61.7 ± 10.7	64.5 ± 8.3	66.2 ± 11.7	61.8 ± 10.6	61.9 ± 12.4	64.1 ± 14.2	63.5 ± 14.2
CS (% AL)	74.4 ± 7.9	74.9 ± 9.5	82.1 ± 9.8	83.8 ± 12.4	80.8 ± 8.5	77.5 ± 9.0	80.2 ± 6.6	81.6 ± 9.9	76.8 ± 9.8	76.7 ± 11.6	77.5 ± 10.9	78.1 ± 10.7
Right arm reach												
MD (% AL)	84.3 ± 9.6	86.8 ± 13.1	92.5 ± 8.4	95.1 ± 9.7	93.1 ± 6.6	94.0 ± 10.0	95.7 ± 10.6	98.3 ± 10.4	93.6 ± 11.5	92.3 ± 9.5	94.4 ± 10.0	95.5 ± 12.8
IL (% AL)	77.0 ± 9.6	75.5 ± 11.7	88.3 ± 13.8	91.0 ± 18.6	82.0 ± 11.4	79.4 ± 10.7	76.3 ± 9.1	75.4 ± 10.4	72.4 ± 10.7	72.3 ± 10.6	75.9 ± 11.2	75.1 ± 12.2
SL (% AL)	56.7 ± 9.3	57.7 ± 12.7	62.2 ± 10.5	62.3 ± 9.5	62.7 ± 8.4	61.3 ± 9.6	61.1 ± 9.8	63.0 ± 11.7	59.5 ± 11.4	60.0 ± 12.0	61.5 ± 9.5	61.1 ± 13.1
CS (% AL)	72.7 ± 7.9	73.3 ± 10.9	81.0 ± 8.8	82.8 ± 10.7	79.3 ± 6.5	78.2 ± 8.0	77.7 ± 7.0	78.9 ± 8.6	75.2 ± 8.7	74.9 ± 8.4	77.3 ± 8.8	77.2 ± 11.0

Values are mean values ± standard deviations. AL = arm length; CS = composite score; IL = inferolateral; MD = medial; SL = superolateral.

12-year-olds, from 0.67-0.88 for 13-year-olds, from 0.63-0.93 for 14-year-olds, from 0.47-0.83 for 15-year-olds, from 0.81-0.90 for 16-year-olds, and from 0.86-0.97 for 17-year-olds (Table 3). In addition, the SEM values ranged from 2.9-6.1% for 12-year-olds, from 3.5-7.4% for 13-year-olds, from 1.9-5.3% for 14-year-olds, from 3.4-7.6% for 15-year-olds, from 2.7-6.0% for 16-year-olds, and from 1.8-4.3% for 17-year-olds (Table 3). Examples of Bland–Altman plots for the CS during left arm reach for each age category are shown in Figure 2 A-F. Overall, the plots illustrate that a relatively large amount of data points (87.5-100%) was within the limits of agreement (i.e., mean ± 1.96 SD lines). For the other measures, the percentages of data points, which were within the limits of agreement, were in the same range (data not shown).

Minimal detectable change

The MDC95% values ranged from 8.1-16.9% for 12-year-olds, from 9.7-20.4% for 13-year-olds, from 5.4-14.8% for 14-year-olds, from 9.5-21.1% for 15-year-olds, from 7.6-16.5% for 16-year-olds, and from 4.8-11.9% for 17-year-olds (Table 4).

Table 3. *Intraclass correlation coefficient with 95% confidence interval and standard error of measurement by age cohort.*

	12 yrs (n=14)		13 yrs (n=20)		14 yrs (n=24)		15 yrs (n=20)		16 yrs (n=18)		17 yrs (n=15)	
	$ICC_{3,1}$ (95% CI)	SEM (%)	$ICC_{3,1}$ (95% CI)	SEM (%)	$ICC_{3,1}$ (95% CI)	SEM (%)	$ICC_{3,1}$ (95% CI)	SEM (%)	$ICC_{3,1}$ (95% CI)	SEM (%)	$ICC_{3,1}$ (95% CI)	SEM (%)
Left arm reach												
MD (% AL)	0.90 (0.68-0.97)	3.3	0.78 (0.44-0.91)	4.6	0.63 (0.15-0.84)	5.2	0.83 (0.56-0.93)	4.6	0.85 (0.63-0.94)	5.5	0.94 (0.82-0.98)	2.9
IL (% AL)	0.80 (0.39-0.94)	4.0	0.83 (0.57-0.93)	7.4	0.90 (0.78-0.96)	4.1	0.57 (-0.08-0.83)	7.3	0.82 (0.54-0.93)	6.0	0.95 (0.84-0.98)	2.5
SL (% AL)	0.71 (0.09-0.91)	5.4	0.80 (0.50-0.92)	4.9	0.81 (0.55-0.92)	5.3	0.78 (0.44-0.91)	4.7	0.85 (0.62-0.94)	4.4	0.97 (0.91-0.99)	2.5
CS (% AL)	0.89 (0.64-0.96)	2.9	0.88 (0.70-0.95)	3.8	0.88 (0.72-0.95)	3.2	0.83 (0.57-0.93)	3.4	0.90 (0.75-0.96)	3.3	0.97 (0.92-0.99)	1.8
Right arm reach												
MD (% AL)	0.82 (0.44 -0.94)	4.8	0.67 (0.17-0.87)	5.2	0.75 (0.41-0.89)	4.4	0.81 (0.53-0.93)	4.5	0.81 (0.51-0.92)	4.6	0.91 (0.72-0.97)	3.5
IL (% AL)	0.67 (-0.04-0.89)	6.1	0.86 (0.64-0.94)	6.2	0.90 (0.77-0.96)	3.5	0.47 (-0.58-0.75)	7.6	0.84 (0.58-0.94)	4.3	0.86 (0.59-0.95)	4.3
SL (% AL)	0.90 (0.67-0.97)	3.5	0.71 (0.27-0.89)	5.3	0.84 (0.63-0.93)	3.7	0.83 (0.56-0.93)	4.5	0.86 (0.64-0.94)	4.3	0.94 (0.81-0.98)	2.8
CS (% AL)	0.87 (0.61-0.96)	3.3	0.87 (0.68-0.95)	3.5	0.93 (0.84-0.97)	1.9	0.80 (0.50-0.92)	3.5	0.90 (0.74-0.96)	2.7	0.94 (0.83-0.98)	2.3

AL = arm length; CI = confidence interval; CS = composite score; $ICC_{3,1}$ = intraclass correlation coefficient; IL = inferolateral; MD = medial; SEM = standard error of measurement; SL = superolateral.

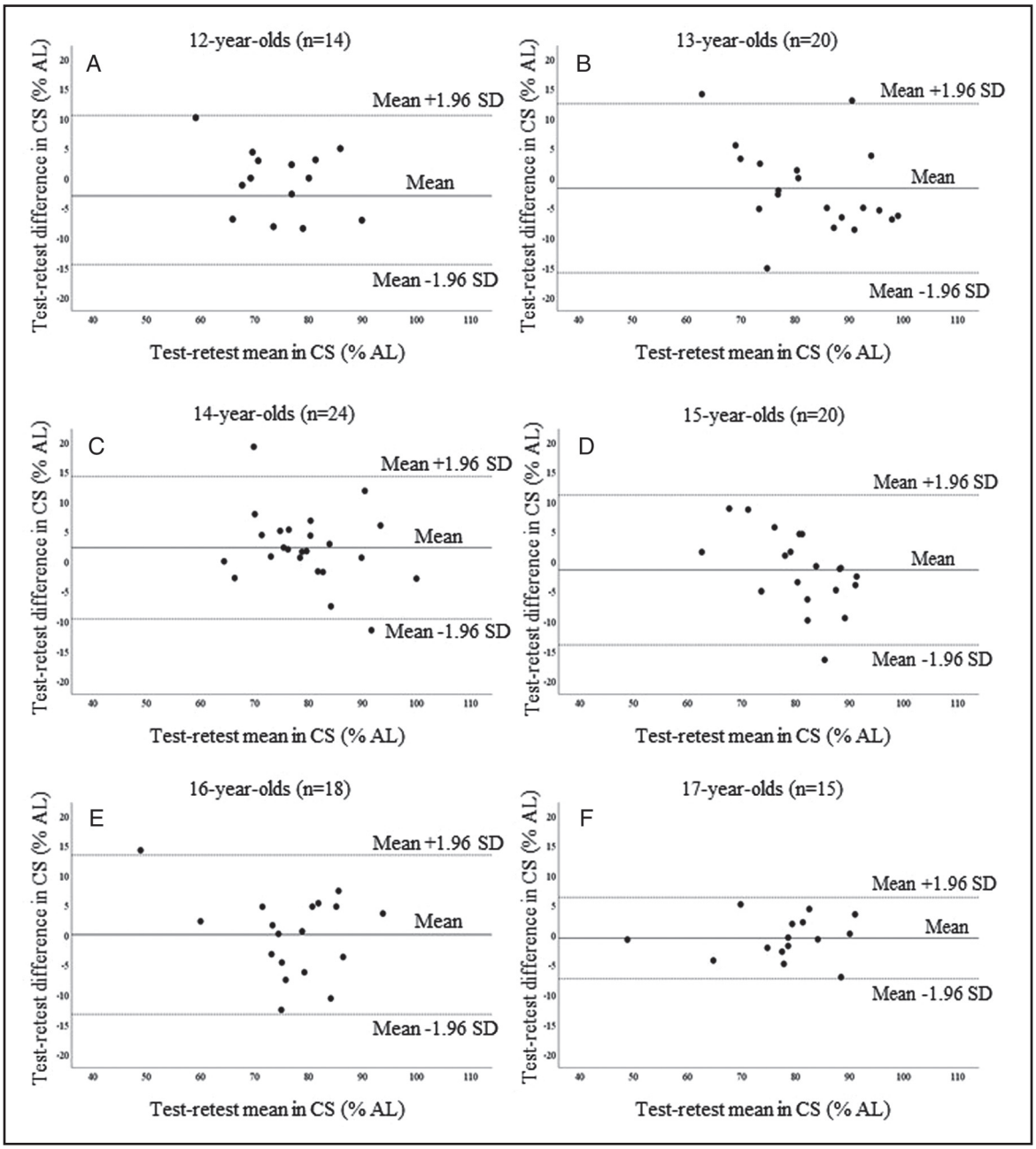

Figure 2. *Bland-Altman plots for the composite score (CS) during left arm reach for the 12-year-olds (A), the 13-year-olds (B), the 14-year-olds (C), the 15-year-olds (D), the 16-year-olds (E), and the 17-year-olds (F). The difference between the test and retest measurements is plotted against the mean of the respective measurements. Solid lines indicate the average of the differences. Dotted lines indicate the mean ± 1.96 standard deviations (i.e., limit of agreement).*

DISCUSSION

In the present study, test-retest reliability of the YBT-UQ was investigated in a relatively large-sized sample of 111 healthy female and male adolescents aged 12-17. With reference to the relevant literature,[1,2] it was expected that the YBT-UQ would be a reproducible test for the assessment of upper quarter mobility and stability in this population.

Given that there is no study available that examined test-retest reliability of the YBT-UQ in healthy adolescents, the present results have to be compared with results originating from studies[1,2] that investigated older age cohorts. For example, Gorman et al.[1] investigated healthy young adults (age range: 19-47 years) and reported ICC values between 0.80 and 0.99 for the three reach directions indicating "excellent"

Table 4. *Minimal detectable change by age cohort.*

	12 yrs (n=14)	13 yrs (n=20)	14 yrs (n=24)	15 yrs (n=20)	16 yrs (n=18)	17 yrs (n=15)
Left arm reach						
MD (% AL)	9.1	12.8	14.5	12.3	15.2	8.0
IL (% AL)	11.2	20.4	11.4	20.2	16.5	7.1
SL (% AL)	15.0	13.5	14.8	13.1	12.3	6.8
CS (% AL)	8.1	10.5	8.9	9.5	9.2	4.8
Right arm reach						
MD (% AL)	13.3	14.5	12.3	12.6	12.7	9.6
IL (% AL)	16.9	17.1	9.6	21.1	11.9	11.9
SL (% AL)	9.8	14.7	10.1	12.3	12.0	7.8
CS (% AL)	9.2	9.7	5.4	9.6	7.6	6.4

AL = arm length; CS = composite score; IL = inferolateral; MD = medial; SL = superolateral.

reliability. Further, Westrick et al.[2] studied healthy, college-aged adults and observed ICC values ranging from 0.91 to 0.92 that are indicative of "excellent" reliability. The present findings are mainly in accordance with the previous studies.[1,2] This implies that the YBT-UQ is a reproducible test that can be used for the assessment of intervention-based (e.g., physical exercise) changes of upper quarter mobility and stability in adolescents from several age cohorts as well as in young adults. However, we observed solely "excellent" ICC values in the 16- and 17-year-olds while the 12- to 15-year-olds crossed over from "moderate-to-good" into "excellent" ICC values. Thus, particular care (e.g., ensuring a high level of attention and concentration by the tested subjects) is needed when performing the YBT-UQ in younger compared to older adolescents. Further, the "excellent" ICC values in the 16- and 17-year-olds corresponds with those obtained in adults[1,2] which seems indicative for the adoption of an adult-like YBT-UQ control in this age group.

The MDC95% ranged between 4.8% and 21.1%. Thus, a change in YBT-UQ performance exceeding these values, seems to be a true response, and an examiner can be 95% confident that a true change has occurred beyond measurement error. In this regard, a study by Salo and Chaconas[12] repeatedly performed the YBT-UQ performance before and after a fatigue protocol in healthy adults (mean age: 26 ± 3 years). The authors reported significant performance reductions of 2 to 18%, which corresponds to the aforementioned MDC95% value range.

Further, the present analyses showed no statistically significant differences in performance on the YBT-UQ between females and males (except for the right arm reach in the IL direction in favour of boys) as well as between the dominant and the non-dominant arm. This is in line with previous studies[1,2,13,14] that investigated sex and/or limb differences in the YBT-UQ performance. For example, Gorman et al.[1] compared normalized YBT-UQ performance between 45 women and 51 men and did not observe statistically significant sex differences. In terms of limb differences, Borms et al.[14] investigated 29 healthy adults and reported no significant differences on the YBT-UQ between the dominant and the non-dominant arm.

The present findings were obtained from typically developing adolescents aged 12 to 17 years and are thus only applicable in healthy adolescents in this specific age group. Thus, these results cannot be generalized to other populations with physical/motor deficits (e.g., adolescents suffering from developmental coordination disorder) or other age groups, such as younger (i.e., children) persons. Further, the presented findings are specific to the YBT-UQ, which is a well-established field-based method of investigating upper quarter mobility and stability.[1-3] As a

consequence, further research is needed to confirm the present results for other upper quarter field tests (e.g., closed kinetic chain upper extremity stability test, seated medicine ball throw).

CONCLUSIONS

The results of the current study indicate "moderate-to-good" to "excellent" ICC values in 12- to 15-year-olds, "excellent" ICC scores in 16- and 17-year-olds, and rather low SEM values (i.e., ≤ 7.6%) when considering all adolescents. These findings indicate that the YBT-UQ is a feasible and reproducible test for the assessment of upper quarter mobility and stability in healthy female and male adolescents aged 12 to 17 years. The observed MDC95% values ranged from 4.8 to 21.1% (depending on age cohort, reach arm, and reach direction) and represent the minimum amount of change needed to exist between pre- and post-testing YBT-UQ scores to indicate a real change in performance. Future research is needed to establish the responsiveness of the YBT-UQ to upper body training and conditioning programs and to determine the amount of training-related performance changes, which may occur in adolescents.

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